

MTTC FILE COPY

MTL TR 88-40

AD

2

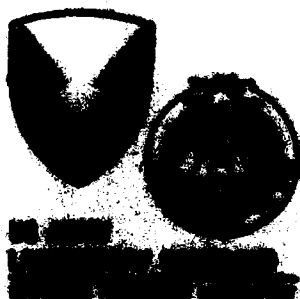
AD-A203 589

**OXIDATION STUDIES OF UNFILLED STYRENE-
BUTADIENE RUBBER USED IN TANK TRACK
PADS BY FT-IR AND DSC**

JAMES M. SLOAN and MARIANNE T. BACHAND
POLYMER RESEARCH BRANCH

November 1988

Approved for public release; distribution unlimited.



DTIC
ELECTE
S JAN 23 1989 D
OH

U.S. ARMY MATERIALS TECHNOLOGY LABORATORY
Watrick, Massachusetts 02172-0001

89 1 23 014

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

Mention of any trade names or manufacturers in this report shall not be construed as advertising nor as an official indorsement or approval of such products or companies by the United States Government.

DISPOSITION INSTRUCTIONS

Destroy this report when it is no longer needed.
Do not return it to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ADA203589

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MTL TR 88-40	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) OXIDATION STUDIES OF UNFILLED STYRENE-BUTADIENE RUBBER USED IN TANK TRACK PADS BY FT-IR AND DSC		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) James M. Sloan and Marianne T. Bachand		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Materials Technology Laboratory Watertown, Massachusetts 02172-0001 SLCMT-EMP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS D/A Project: IT161101A91A
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Laboratory Command 2800 Powder Mill Road Adelphi, Maryland 20783-1145		12. REPORT DATE November 1988
		13. NUMBER OF PAGES 10
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Elastomers, STYRENE, BUTADIENE, RUBBER, TANK TREADS, M-1 ABRAMS - TANK, Infrared spectroscopy, COMBAT VEHICLE, INFRARED ANALYSIS, POWER TRANSDUCER, Thermal analysis, Tank track pads. <i>GED</i>		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (SEE REVERSE SIDE)		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block No. 20

ABSTRACT

↙ The thermo-oxidation of unfilled styrene-butadiene rubber (SBR) was examined by Fourier transform infrared spectroscopy and differential scanning calorimetry (DSC). The process was found to follow an auto-oxidative reaction sequence, where formation of alkyl and peroxy radicals is the initial step. It was also determined that only the butadiene portion of the copolymer was oxidized, no oxidation of the styrene portion could be detected. The DSC results yielded enthalpies in the range of 90 to 180 J/g with an activation energy of 35.0 kcal/mole. *Keywords* →



Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Availability/	
Dist	Serial
A-1	

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

INTRODUCTION

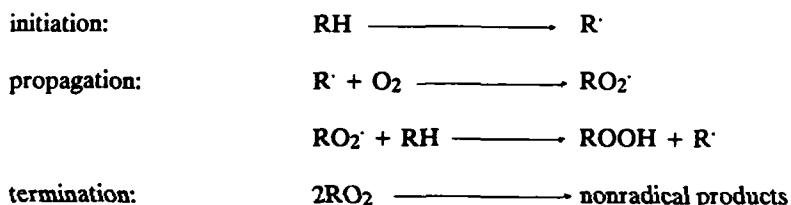
Industrial elastomers degrade more rapidly on continued exposure to sunlight and elevated temperatures in the presence of oxygen.^{1,2,3} As a consequence of this oxidative degradation, progressive deterioration of physical and mechanical properties are realized.

Styrene-butadiene rubber (SBR) is presently the major component elastomer used to make track pads for the Army's M-1 Abram's tank. Replacement costs for these track pads currently run the Army over \$150 M a year. Development of high performance elastomers which can handle the operational requirements for track pads is a difficult problem. One approach is to improve the materials currently in use. The first step is to evaluate various failure modes and degradation processes occurring in the elastomers.

Elastomers with an unsaturated backbone are known to be more susceptible toward oxidative degradation. In fact, oxidative degradation is the primary method for deterioration of polymers under normal use. In this report, the thermo-oxidation of an unfilled SBR is studied. Fourier transform infrared spectroscopy (FT-IR) is used to determine the mechanism of oxidation of SBR, while differential scanning calorimetry (DSC) is used to determine the thermodynamic parameters and kinetics of oxidation.

BACKGROUND

The free radical mechanism of oxidation of elastomers proceeds through a chain reaction according to a well-established sequence of reactions.^{4,5} The scheme is as follows:



where RH represents a hydrocarbon, R^{\cdot} an alkyl radical, and RO_2^{\cdot} a peroxy radical.

This relatively simple sequence of reactions can be complicated when oxidizable impurities are present. Also, there is a possibility that secondary processes can occur, where peroxides and free radicals undergo chain scission reactions. It is, therefore, assumed that the degree of deterioration of physical properties is generally proportional to the degree of oxidation.⁶

DATA ANALYSIS

The oxidation reaction of the SBR exhibits an exothermic maximum in the DSC thermogram. The reaction enthalpy can then be determined by calculating the area under the curve. From these curves, the thermodynamic parameters and kinetics can be determined.

1. HAWKINS, W.L., ed. *Polymer Stabilization*. Wiley-Interscience, New York, 1972.
2. BAMFORD, C.H., and TIPPER, C.F.H. *Degradation of Polymers*. Elsevier, New York, v. 19, 1975, p. 153.
3. GUSKENS, G. ed. *Degradation and Stabilization of Polymers*. Applied Science, 1975, p. 1.
4. SWERN, D., URI, N., MESROBIAN, R.B., and TOBOLSKY, A.V. *Auto-oxidation and Antioxidants Volume VI*, Interscience Publishers of John Wiley and Sons, New York, 1961, p. 97.
5. CUNEEN, J.I. *Oxidative Aging of Natural Rubber*. Rubber Chemical Technology, v. 41, 1968, p. 182.
6. AMIBELANG, J.C., KLINE, R.H., LORENY, O.M., PARKS, C.R., WALDEN, C., and SHELTON, J.R. *Antioxidants and Antioxidants for General Purpose Elastomers*. Rubber Chemical Technology, v. 48, 1972, p. 1497.

The Borchardt-Daniels⁷ method was used to determine the energy of activation. The reaction is assumed to be first order in SBR and can be expressed as follows:

$$k = Ae^{-E_a/RT}$$

where k is the scanning rate constant, A is a pre-exponential factor, E_a is the energy of activation for the oxidation reaction, T is the temperature maxima, and R is the general constant in the gaseous state.

This equation can be reduced to a more usable form to yield:

$$\ln k = -\frac{E_a}{R} \frac{1}{T} + \ln A$$

$$\log k = -\frac{E_a}{R} \frac{2.3}{T} + \log A$$

This equation produces a linear graph with the slope equal to $E_a(2.3)/R$, from which the energy of activation can be calculated.

EXPERIMENTAL

SBR-1502 was used as the base rubber. This was obtained from the Goodyear Tire and Rubber Company. No further purification was done. The rubber was dissolved in toluene and cast as a thin film onto a KBr salt plate. The toluene was then evaporated by streaming dry nitrogen over the salt plate. The KBr plate was then incubated at specified time intervals in a thermostatted oven with an atmospheric air purge. The temperature used for this study was 120°C.

The infrared spectra were obtained on a Perkin-Elmer Model 1550 Fourier transform infrared spectrometer equipped with a Model 7500 PE computer. The spectra were transferred to a floppy disk for data reduction at a later time. The spectra were taken at 4 cm⁻¹ resolution for 16 co-added scans.

DSC measurements were taken on a DuPont Model 910 differential scanning calorimeter cell with a DuPont Model 1090 controller. The sample was weighed and placed in an aluminum pan. A purge of dry air or dry nitrogen was used depending on the environment desired. The DSC curves were produced by heating the sample from room temperature to 400°C at a heating rate of 2, 5, 10, and 20 degrees per minute.

RESULTS AND DISCUSSION

Fourier Transform Infrared Spectroscopy

Figure 1 shows the infrared spectrum of the SBR at time zero and three spectra at various stages of thermo-oxidation. The initial spectrum shows no indications of premature oxidation although a band at 1700 cm⁻¹ is visible. This is presumed to be an absorption due to carboxylated end groups. During the polymerization process, the end groups are capped with carbonyl groups to obtain the desired molecular weight.

The top three spectra begin to show various stages of oxidation. Strong absorptions appear at 3450 cm⁻¹, 1720 cm⁻¹, and in the 1000-1200 cm⁻¹ range. These bands are increasing with reaction time and are due to oxidation products being formed.

7. BORCHARDT, H.J., and DANIELS, H. *Application of Differential Thermal Analysis to the Study of Reaction Kinetics*. Journal of the American Chemical Society, v. 79, 1957, p. 41.

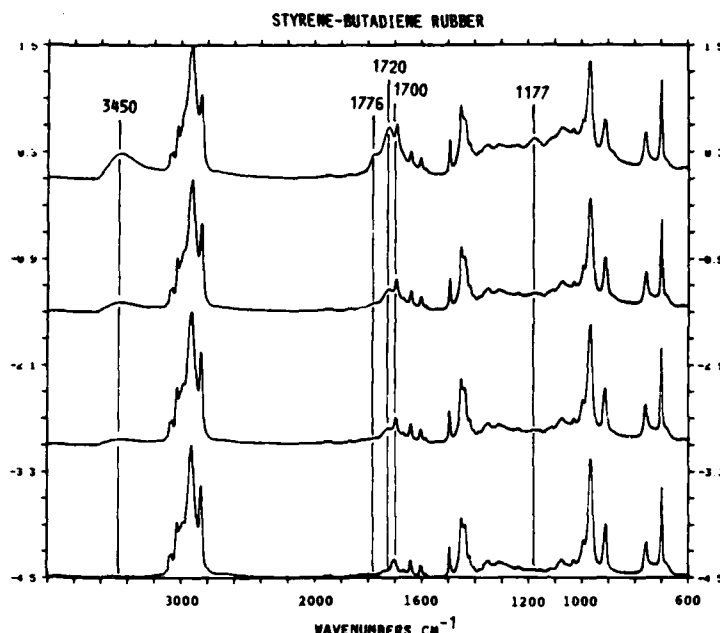


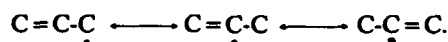
Figure 1. Styrene-butadiene rubber oxidation: progressive stages of oxidation are seen. Bottom spectrum, time zero spectrum, followed by spectra at 50 minutes, 60 minutes and 90 minutes, respectively.

Figure 2 shows two subtraction spectra of successive IR oxidation spectra. The bottom spectrum is that of 60 minutes minus 50 minutes. The top spectrum is 90 minutes minus 60 minutes. These subtraction spectra show IR band changes not seen in Figure 1. Negative bands can be observed at 3007 cm^{-1} and 3065 cm^{-1} . Also, negative bands appear at 910 cm^{-1} and 964 cm^{-1} . These bands are related in that they are due to the cis C-H on the double bond. The 3007 cm^{-1} and 3065 cm^{-1} have been assigned to the symmetric and asymmetric stretch of the =C-H. Similarly, the 910 cm^{-1} bands are due to the vinyl C=C-H, and cis C=C-H wags, respectively. This is the first step in the oxidative process, the abstraction of the α -methylene hydrogen. This then becomes the site of the alkyl radical.

New absorbing species become apparent at this stage. IR bands at 1050 cm^{-1} due to C-O, at 1720 cm^{-1} due to C=O, and at 3450 cm^{-1} due to O-H appear. All show the incorporation of oxygen into the elastomer. The broadness of these bands demonstrate the fact that many different types of absorbing species are present. The appearance of the 1050 cm^{-1} band is attributed to C-O absorption and most likely due to the original formation of peroxy radical groups, $\text{RO}_2\cdot$. The subsequent formation of ROOH is demonstrated by the appearance of the O-H species at 3450 cm^{-1} , and by the C=O group at 1720 cm^{-1} .

Figure 3 shows the major spectral changes with time. The bands at 3007 cm^{-1} , 3065 cm^{-1} and 964 cm^{-1} all behave in the same manner. This is clear in that they have the same shape on the graph. These are all due to the disappearance of the cis =C-H on the double bonded carbon. Similarly, the bands at 1720 cm^{-1} , 3450 cm^{-1} and 1050 cm^{-1} appear to be related. These are all due to various functional groups associated with incorporation of oxygen into the elastomer. The appearance of these bands is consistent with the auto-oxidation sequence found in the Background section of this report.

It is reasonable to suggest that the α -methylene hydrogen is the hydrogen that gets abstracted. Energetically, it is the one that is most favorable. This forms the alkyl radical depicted in the auto-oxidative sequence. It becomes possible for this radical to then form a resonance structure with the adjacent double bond before attack by atmospheric O_2 . It is believed that the resonance structure can be expressed as follows:



This is the reason the IR spectra show a decrease in the 3007 cm^{-1} and 3065 cm^{-1} bands, those assigned to the methylenic hydrogens.

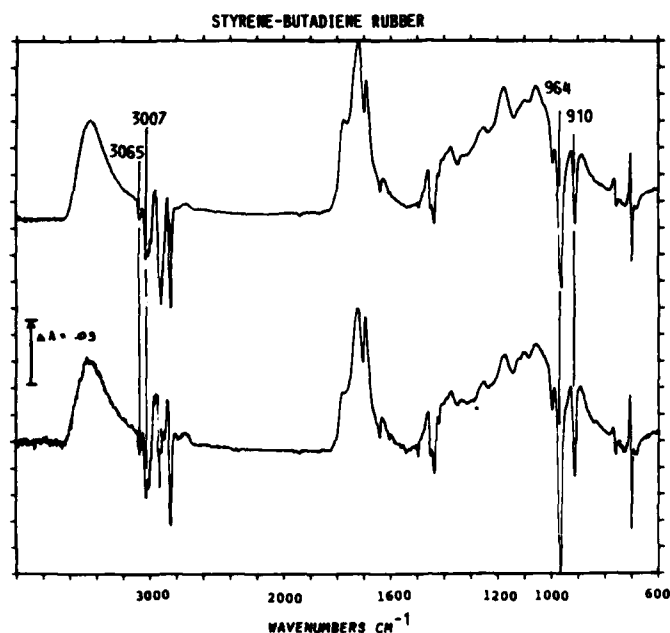


Figure 2. Difference spectra from successive oxidation spectra. Bottom, 60 minutes minus 50 minutes; Top, 90 minutes minus 60 minutes.

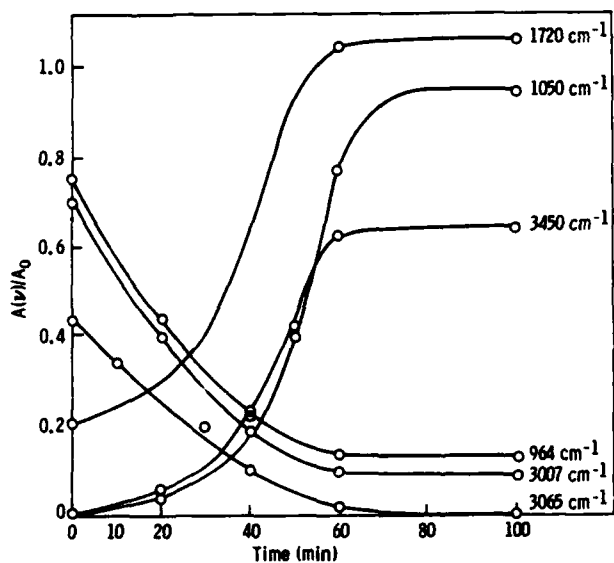


Figure 3. IR band changes with time in the oxidation of SBR at 120°C.

After the major spectral changes have manifested themselves, several small shoulders begin to appear at 1700 cm^{-1} and 1727 cm^{-1} . These have been assigned to saturated and unsaturated aldehydes, respectively. Also, the appearance of shoulders at 1776 cm^{-1} and 1177 cm^{-1} are due to lactone structures caused by reorganization of the polymer backbone

and pendant side chain oxidation products. It should be pointed out that only the polybutadiene portion of the elastomer undergoes thermo-oxidation. The absence of an IR band at 3550 cm^{-1} , where ArO-H stretch would appear, demonstrates the fact that the polystyrene portion of the copolymer does not undergo thermo-oxidation.

Table 1 summarizes the IR band changes for the oxidation process.

Table 1. INFRARED BAND ASSIGNMENTS

Band	Assignment	Change
910	Terminal C=C	-
960	cis C=C	-
1050	C-O	+
1140	C-O	+
1177	C-O, Possible Lactone Groups	+
1700	Unsaturated Aldehyde	+
1720	C=O, Ketonic	+
1727	Saturated Aldehyde	+
1776	C=O, Lactone Groups	+
3007	cis C-H	-
3068	cis C-H	-
3450	O-H	+

Differential Scanning Calorimetry

Figure 4 shows the DSC thermogram for SBR with a nitrogen purge. No exothermic or endothermic transition can be detected. However, if one measures the thermogram with an air purge, a clear exothermic transition can be observed between 210°C and 245°C . Figures 5 through 8 demonstrate the effect of scanning rate on enthalpy and transition temperature maximum. As one increases the scanning rate, T_{max} increases while ΔH decreases. One can then employ the Borchardt-Daniels⁷ method of determining the energy of activation. Figure 9 shows a plot of \log rate versus $1/T$ which is linear. The slope of this line gives an activation energy of 35.0 kcal/mole . This value is somewhat larger than values previously reported.⁸ It is, however, suspected that since such a small sample size is used for the DSC measurement (10-20 mg) that the thermo-oxidation reaction is more complete. The limitations of O_2 diffusion throughout the sample is not a factor as it would be in a bulk sample.

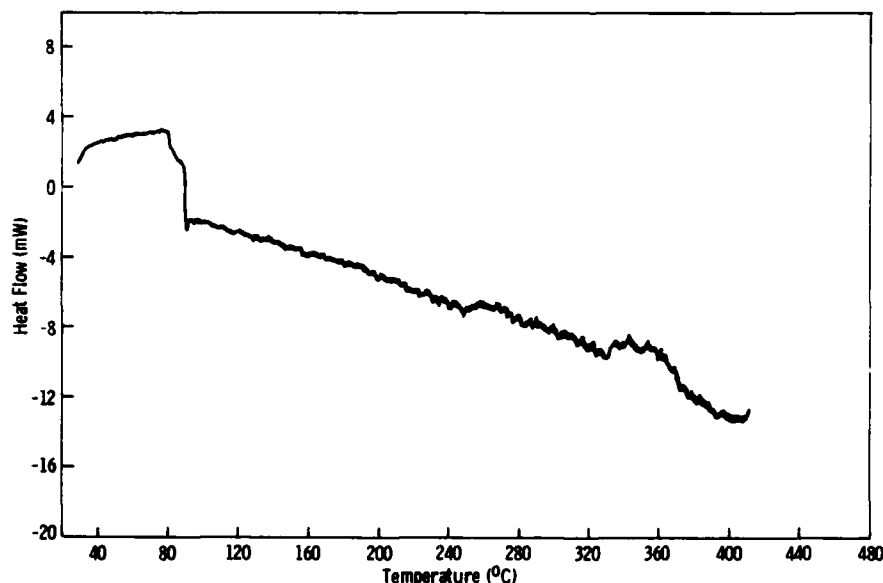


Figure 4. DSC thermogram of SBR with nitrogen purge.

8. PONCE-VELEZ, M.A., and CAMPOS-LOPEZ, E. *The Thermal Oxidation of Guayule and Hevea Rubbers by Dynamic Differential Scanning Calorimetry*. Journal of the Applied Polymer Science, v. 22, 1978, p. 2485.

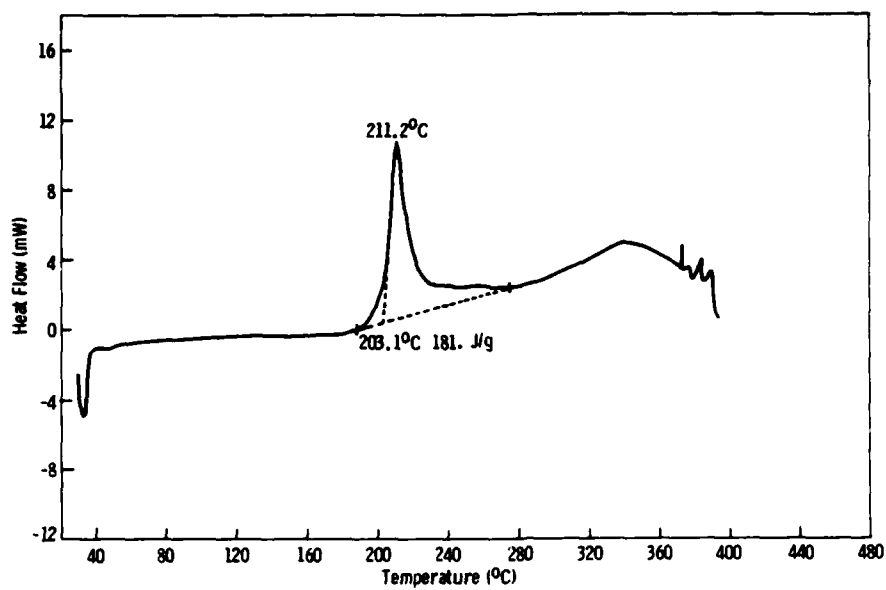


Figure 5. DSC thermogram of SBR oxidation with a scanning rate of 2°C/minute.

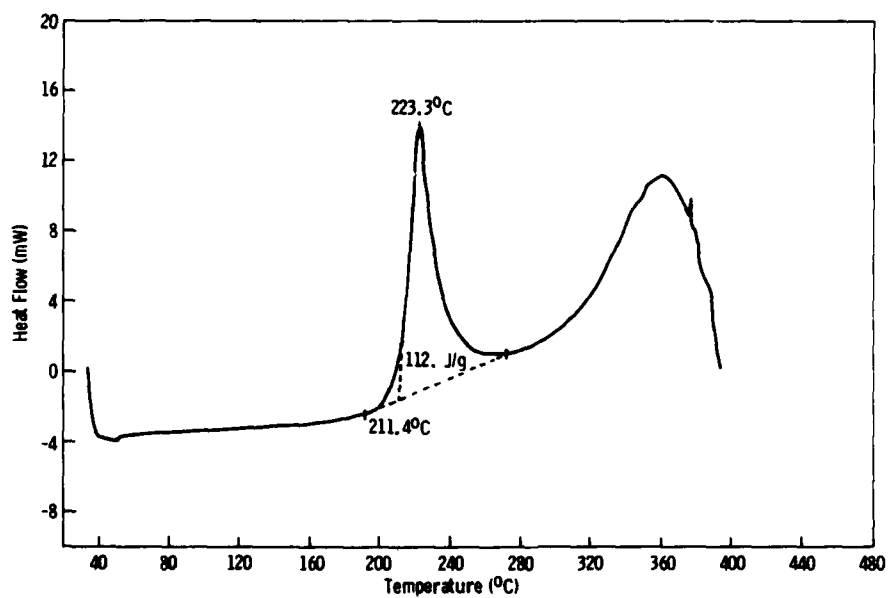


Figure 6. DSC thermogram of SBR oxidation with a scanning rate of 5°C/minute.

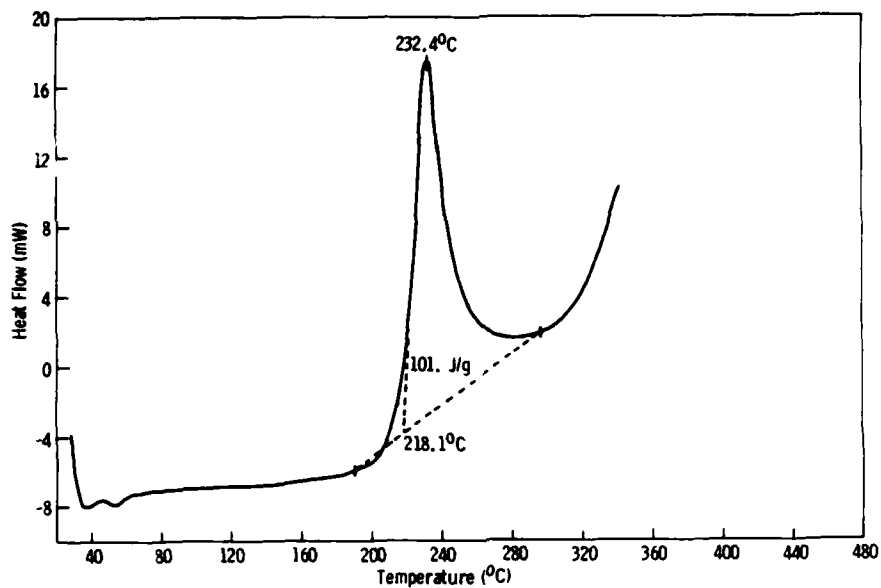


Figure 7. DSC thermogram of SBR oxidation with a scanning rate of 10°C/minute.

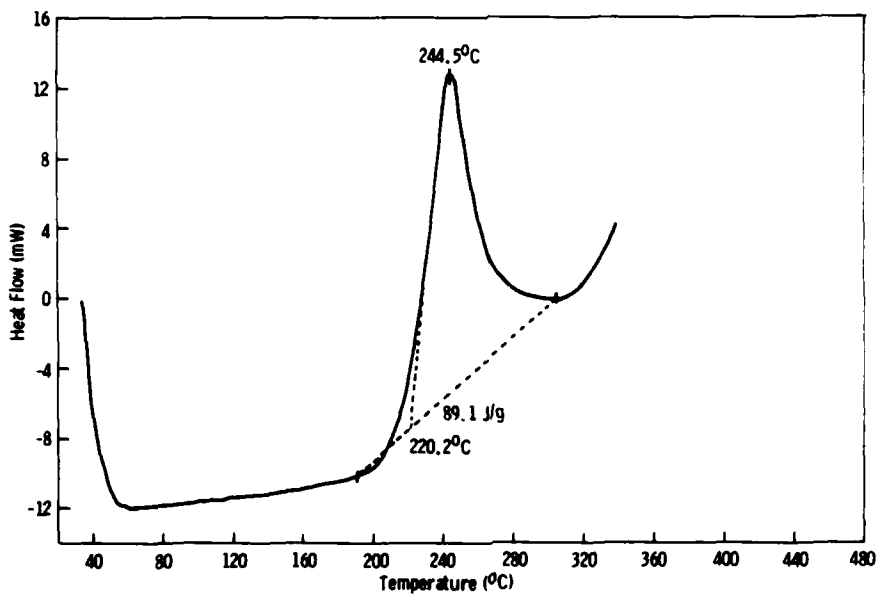


Figure 8. DSC thermogram of SBR oxidation with a scanning rate of 20°C/minute.

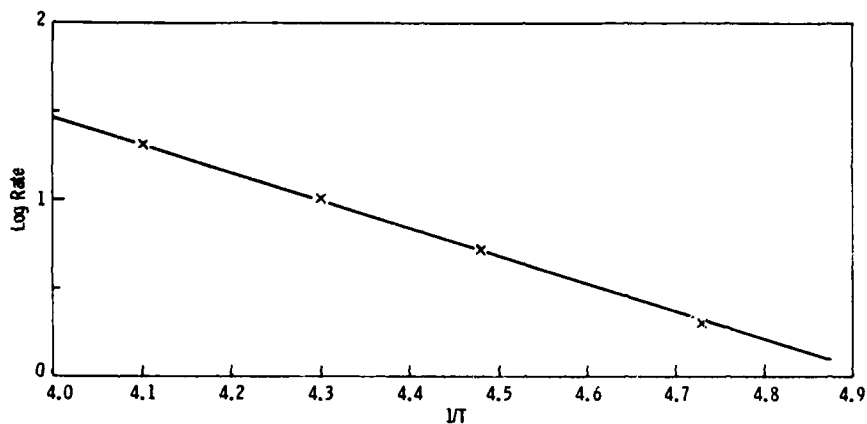


Figure 9. Borshardt and Daniels plot of log rate versus $1/T$.

CONCLUSIONS

The thermo-oxidation of styrene-butadiene rubber was studied by FT-IR and DSC. The FT-IR results suggest that the thermo-oxidation degradation is related to the auto-oxidative degradation process postulated by Cuneen⁵. The DSC results yield enthalpy values in the range 90 to 180 J/g depending on scanning rate with an energy of activation of 35.0 kcal/mole.

It was also found that the degradation is localized only to the polybutadiene portion of the copolymer. No oxidation of the polystyrene was observed.

DISTRIBUTION LIST

No. of Copies	To
1	Office of the Under Secretary of Defense for Research and Engineering, The Pentagon, Washington, DC 20301
	Commander, U.S. Army Laboratory Command, 2800 Powder Mill Road, Adelphi, MD 20783-1145
1	ATTN: AMSLC-IM-TL
	Commander, Defense Technical Information Center, Cameron Station, Building 5, 5010 Duke Street, Alexandria, VA 22304-6145
2	ATTN: DTIC-FDAC
1	Metals and Ceramics Information Center, Battelle Columbus Laboratories, 505 King Avenue, Columbus, OH 43201
	Commander, Army Research Office, P.O. Box 12211, Research Triangle Park, NC 27709-2211
1	ATTN: Information Processing Office
	Commander, U.S. Army Materiel Command, 5001 Eisenhower Avenue, Alexandria, VA 22333
1	ATTN: AMCLD
	Commander, U.S. Army Materiel Systems Analysis Activity, Aberdeen Proving Ground, MD 21005
1	ATTN: AMXSY-MP, H. Cohen
	Commander, U.S. Army Electronics Research and Development Command, Fort Monmouth, NJ 07703
1	ATTN: AMDSD-L
1	AMDSD-E
	Commander, U.S. Army Missile Command, Redstone Scientific Information Center, Redstone Arsenal, AL 35898-5241
1	ATTN: AMSMI-RKP, J. Wright, Bldg. 7574
1	AMSMI-RD-CS-R/ILL Open Lit
1	AMSMI-RLM
	Commander, U.S. Army Armament, Munitions and Chemical Command, Dover, NJ 07801
2	ATTN: Technical Library
1	AMDAR-LCA, Mr. Harry E. Peibly, Jr., PLASTEC, Director
	Commander, U.S. Army Natick Research, Development, and Engineering Center, Natick, MA 01760
1	ATTN: Technical Library
	Commander, U.S. Army Satellite Communications Agency, Fort Monmouth, NJ 07703
1	ATTN: Technical Document Center
	Commander, U.S. Army Tank-Automotive Command, Warren, MI 4397-5000
1	ATTN: AMSTA-ZSK
2	AMSTA-TSL, Technical Library
	Commander, White Sands Missile Range, NM 88002
1	ATTN: STEWS-WS-VT
	President, Airborne, Electronics and Special Warfare Board, Fort Bragg, NC 28307
1	ATTN: Library
	Director, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD 21005
1	ATTN: SLCBR-TSB-S (STINFO)
	Commander, Dugway Proving Ground, Dugway, UT 84022
1	ATTN: Technical Library, Technical Information Division
	Commander, Harry Diamond Laboratories, 2800 Powder Mill Road, Adelphi, MD 20783
1	ATTN: Technical Information Office
	Director, Benet Weapons Laboratory, LCWSL, USA AMCCOM, Watervliet, NY 12189
1	ATTN: AMSMC-LCB-TL
1	AMSMC-LCB-R
1	AMSMC-LCB-RM
1	AMSMC-LCB-RP
	Commander, U.S. Army Foreign Science and Technology Center, 220 7th Street, N.E., Charlottesville, VA 22901
1	ATTN: Military Tech

No. of Copies	To
1	Commander, U.S. Army Aeromedical Research Unit, P.O. Box 577, Fort Rucker, AL 36360 ATTN: Technical Library
1	Director, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, VA 23604-5577 ATTN: SAVDL-E-MOS (AVSCOM)
1	U.S. Army Aviation Training Library, Fort Rucker, AL 36360 ATTN: Building 5906-5907
1	Commander, U.S. Army Agency for Aviation Safety, Fort Rucker, AL 36362 ATTN: Technical Library
1	Commander, USACDC Air Defense Agency, Fort Bliss, TX 79916 ATTN: Technical Library
1	Commander, U.S. Army Engineer School, Fort Belvoir, VA 22060 ATTN: Library
1	Commander, U.S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, MS 39180 ATTN: Research Center Library
1	Commandant, U.S. Army Quartermaster School, Fort Lee, VA 23801 ATTN: Quartermaster School Library
1	Naval Research Laboratory, Washington, DC 20375 ATTN: Code 5830
2	Dr. G. R. Yoder - Code 6384
1	Chief of Naval Research, Arlington, VA 22217 ATTN: Code 471
1	Edward J. Morrissey, AFWAL/MLTE, Wright-Patterson Air Force, Base, OH 45433
1	Commander, U.S. Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, OH 45433 ATTN: AFWAL/MLC
1	AFWAL/MLLP, M. Forney, Jr.
1	AFWAL/MLBC, Mr. Stanley Schulman
1	National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, AL 35812 ATTN: R. J. Schwinghammer, EH01, Dir, M&P Lab
1	Mr. W. A. Wilson, EH41, Bldg. 4612
1	U.S. Department of Commerce, National Bureau of Standards, Gaithersburg, MD 20899 ATTN: Stephen M. Hsu, Chief, Ceramics Division, Institute for Materials Science and Engineering
1	Committee on Marine Structures, Marine Board, National Research Council, 2101 Constitution Ave., N.W., Washington, DC 20418
1	Librarian, Materials Sciences Corporation, Guynedd Plaza 11, Bethlehem Pike, Spring House, PA 19477
1	The Charles Stark Draper Laboratory, 68 Albany Street, Cambridge, MA 02139
1	Wyman-Gordon Company, Worcester, MA 01601 ATTN: Technical Library
1	Lockheed-Georgia Company, 86 South Cobb Drive, Marietta, GA 30063 ATTN: Materials and Processes Engineering Dept. 71-11, Zone 54
1	General Dynamics, Convair Aerospace Division, P.O. Box 748, Fort Worth, TX 76101 ATTN: Mfg. Engineering Technical Library
1	Mechanical Properties Data Center, Belfour Stulen Inc., 13917 W. Bay Shore Drive, Traverse City, MI 49684
1	Mr. R. J. Zentner, EAI Corporation, 626 Towne Center Drive, Suite 205, Joppatowne, MD 21085-4440
2	Director, U.S. Army Materials Technology Laboratory, Watertown, MA 02172-0001 ATTN: SLCMT-TML
2	Authors

U.S. Army Materials Technology Laboratory
Watertown, Massachusetts 02172-0001
OXIDATION STUDIES OF UNFILLED STYRENE-
BUTADIENE RUBBER USED IN TANK TRACK PADS
BY FT-IR AND DSC - James M. Sloan and
Marianne T. Bachand

AD UNCLASSIFIED
UNLIMITED DISTRIBUTION

Key Words

Technical Report MTL TR 88-40, November 1988, 10 pp-
illus-table, D/A Project IT161101A91A

Elastomers
Infrared spectroscopy
Thermal analysis

The thermo-oxidation of unfilled styrene-butadiene rubber (SBR) was examined by Fourier transform infrared spectroscopy and differential scanning calorimetry (DSC). The process was found to follow an auto-oxidative reaction sequence, where formation of alkyl and peroxy radicals is the initial step. It was also determined that only the butadiene portion of the co-polymer was oxidized, no oxidation of the styrene portion could be detected. The DSC results yielded enthalpies in the range of 90 to 180 J/g with an activation energy of 35.0 kcal/mole.

U.S. Army Materials Technology Laboratory
Watertown, Massachusetts 02172-0001
OXIDATION STUDIES OF UNFILLED STYRENE-
BUTADIENE RUBBER USED IN TANK TRACK PADS
BY FT-IR AND DSC - James M. Sloan and
Marianne T. Bachand

AD UNCLASSIFIED
UNLIMITED DISTRIBUTION

Key Words

Technical Report MTL TR 88-40, November 1988, 10 pp-
illus-table, D/A Project IT161101A91A

Elastomers
Infrared spectroscopy
Thermal analysis

The thermo-oxidation of unfilled styrene-butadiene rubber (SBR) was examined by Fourier transform infrared spectroscopy and differential scanning calorimetry (DSC). The process was found to follow an auto-oxidative reaction sequence, where formation of alkyl and peroxy radicals is the initial step. It was also determined that only the butadiene portion of the co-polymer was oxidized, no oxidation of the styrene portion could be detected. The DSC results yielded enthalpies in the range of 90 to 180 J/g with an activation energy of 35.0 kcal/mole.

U.S. Army Materials Technology Laboratory
Watertown, Massachusetts 02172-0001
OXIDATION STUDIES OF UNFILLED STYRENE-
BUTADIENE RUBBER USED IN TANK TRACK PADS
BY FT-IR AND DSC - James M. Sloan and
Marianne T. Bachand

AD UNCLASSIFIED
UNLIMITED DISTRIBUTION

Key Words

Technical Report MTL TR 88-40, November 1988, 10 pp-
illus-table, D/A Project IT161101A91A

Elastomers
Infrared spectroscopy
Thermal analysis

The thermo-oxidation of unfilled styrene-butadiene rubber (SBR) was examined by Fourier transform infrared spectroscopy and differential scanning calorimetry (DSC). The process was found to follow an auto-oxidative reaction sequence, where formation of alkyl and peroxy radicals is the initial step. It was also determined that only the butadiene portion of the co-polymer was oxidized, no oxidation of the styrene portion could be detected. The DSC results yielded enthalpies in the range of 90 to 180 J/g with an activation energy of 35.0 kcal/mole.

U.S. Army Materials Technology Laboratory
Watertown, Massachusetts 02172-0001
OXIDATION STUDIES OF UNFILLED STYRENE-
BUTADIENE RUBBER USED IN TANK TRACK PADS
BY FT-IR AND DSC - James M. Sloan and
Marianne T. Bachand

AD UNCLASSIFIED
UNLIMITED DISTRIBUTION

Key Words

Technical Report MTL TR 88-40, November 1988, 10 pp-
illus-table, D/A Project IT161101A91A

Elastomers
Infrared spectroscopy
Thermal analysis

The thermo-oxidation of unfilled styrene-butadiene rubber (SBR) was examined by Fourier transform infrared spectroscopy and differential scanning calorimetry (DSC). The process was found to follow an auto-oxidative reaction sequence, where formation of alkyl and peroxy radicals is the initial step. It was also determined that only the butadiene portion of the co-polymer was oxidized, no oxidation of the styrene portion could be detected. The DSC results yielded enthalpies in the range of 90 to 180 J/g with an activation energy of 35.0 kcal/mole.